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RECOVERY OF TAR FROM TAR SANDS

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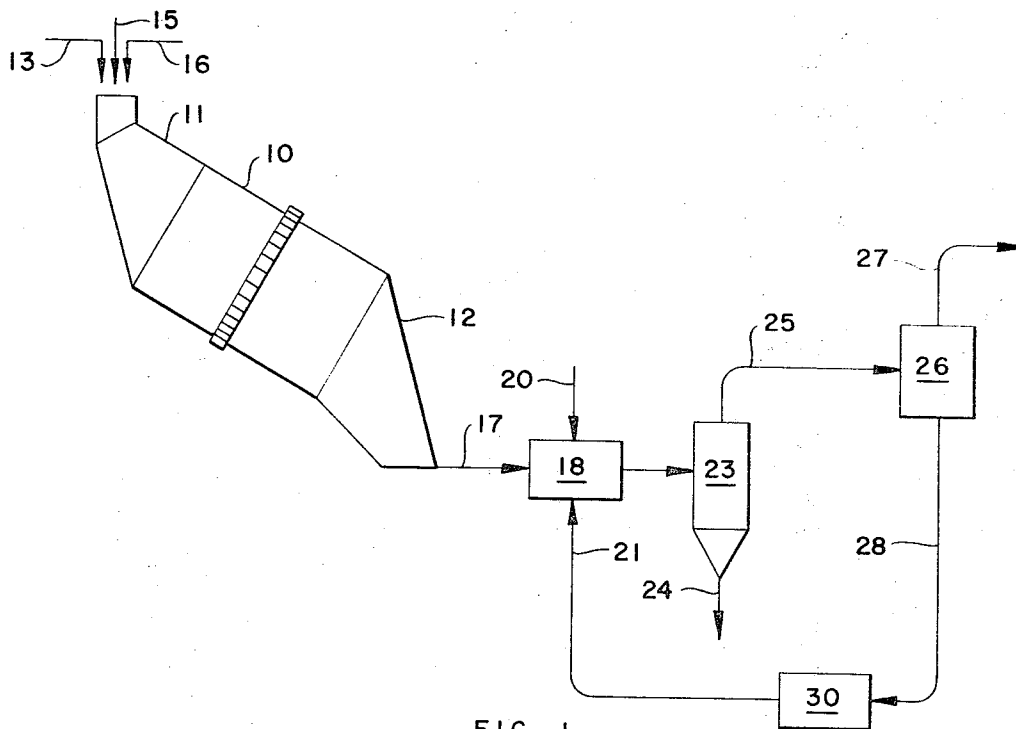


FIG. 1

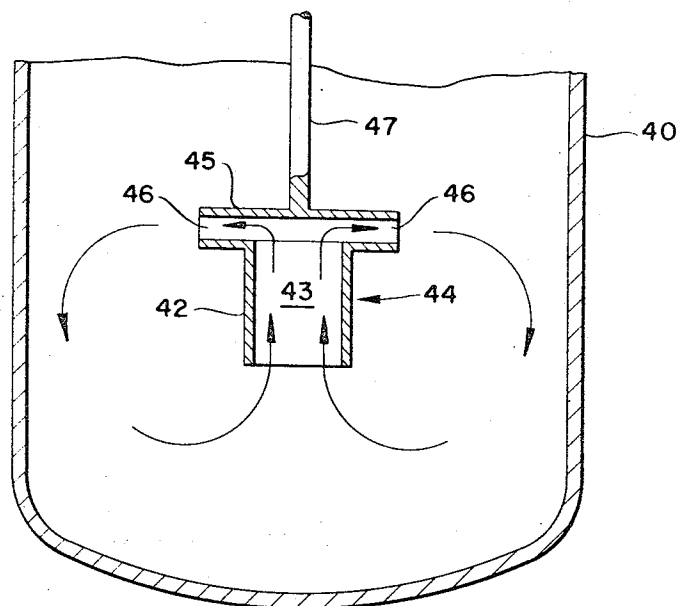


FIG. 2

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RECOVERY OF TAR FROM TAR SANDS

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6 Claims

ABSTRACT OF THE DISCLOSURE

Separating tar from tar sand in a process including mixing tar sand with a hydrocarbon solvent to produce a mixed phase system including a hydrocarbon phase and a solid phase, introducing the mixture into a flowing aqueous stream under such conditions that the hydrocarbon phase has a maximum viscosity of two poises, that the differential velocity between each particle of sand and the flowing aqueous stream produces a Reynolds number of at least 150 in the system including the particle of sand and the surrounding aqueous phase, and that the volume ratio of aqueous phase to tar sand, exclusive of solvent, is at least four, and separately recovering solid phase, aqueous phase, and hydrocarbon phase.

BACKGROUND

As sources of crude oil become less available, there is a greater need to develop known but less easily handled petroleum resources. One such resource is tar sand, which is a sandy material having both water and tar within its interstices. Tar sand occurs in natural deposits which may be mined. Before the petroleum material in the tar sand can be employed in ordinary oil refining operations, it must be separated from the solid, sandy material.

Many general approaches have been employed to recover tar from tar sands. The use of solvents for tar is effective in removing the tar from the sand, but solvent extraction processes usually involve large solvent losses that cannot be tolerated if the process is to be economical enough to compete with liquid crude sources. Since the volume of solids in tar sand is so great compared with the volume of pore space, usually the tar content is less than 15 percent of the total tar sand material; and the value of the tar is so small compared with the value of the solvent that even small percentage losses of solvent in the large volume of discarded sand cannot be tolerated. Retorting of tar sand has also been employed, but high energy costs and low yields make retorting an unattractive process for recovering petroleum. The high cost of separating tar from sand has been the largest restriction on the use of tar sand as an economic source of crude petroleum.

THE INVENTION

This invention deals with a method for recovering tar from tar sand substantially without loss of solvent and without high energy costs. The method is based on preparing tar sand to have certain critical physical characteristics and then subjecting each particle of the tar sand to a high energy shearing treatment in an aqueous phase wherein a critical amount of kinetic energy is expended on each particle of tar sand. When these critical relationships are employed, there is substantially complete recovery of tar and solvent as a gravitationally separated hydrocarbon phase; and substantially all of the liquid losses in the discarded sand fraction involve the inexpensive and readily replaced aqueous phase.

Although this invention is not limited to previous preparations, the process obviously will function more eco-

nomically if the tar sand is crushed to suitable size before being processed. The process of this invention is initiated by preparing tar sand to be in a specific predetermined condition by mixing it with a solvent and, if necessary, adjusting the temperature of the mixture. The objective of this first step in the process is to produce a hydrocarbon phase, which includes the tar and the solvent, having a maximum viscosity of two poises and preferably a viscosity of less than one poise. Such a hydrocarbon phase can be prepared by employing a light hydrocarbon solvent such as gasoline, which will produce a hydrocarbon phase when mixed with the tar that has the required viscosity at ambient temperature.

When heat energy is available, the hydrocarbon phase at proper viscosity may be produced with a heavier solvent such as gas oil if the mixture is heated to at least 50° C. The preferred mode of operation will depend upon the conditions that prevail. If heat energy is available, reducing viscosity through temperature elevation may be preferred because a less volatile solvent can be employed; but if processing is at a mine site where heat is not available inexpensively, a lighter hydrocarbon, which reduces the viscosity of the resultant hydrocarbon phase without heat, is preferred.

Mixing of tar sand and hydrocarbon solvent is accomplished in a low energy mixer such as a muller or rotary drum. Mixing of hydrocarbon and tar sand may be in the presence of water or other material to aid in handling. For example, added water may be included in the hydrocarbon-sand mixture to produce a slurry for transporting the mixture to the next step in the process.

The resultant mixture of hydrocarbon solvent and sand, with or without added water, is subjected to treatment that produces a predetermined amount of shearing on each particle of sand. This treatment involves introducing each particle of sand into a flowing aqueous stream in such manner that there is sufficient difference in velocity between the sand and the aqueous stream to produce a Reynolds number in the system including a sand particle and the surrounding water of at least 150. This portion of the process should not be confused with stirring or mixing because the criteria are quite different. This portion of the process requires that the sand and water have greatly different relative velocities so that a rapid acceleration of each sand particle is effected to produce strong shear forces at the surface of the sand particles. Flow may be quite smooth, for example, when the sand-solvent mixture is introduced into the throat of a Venturi in which there is rapid flow of water. Stirring in its usual sense is not indicated because in ordinary stirring both the solid phase and the liquid phase might be at high velocity, and acceleration of the solid particles by the liquid phase might be quite small.

In the sense of accelerating a sand particle in an aqueous phase, the Reynolds number found to be critical is a special case of the Reynolds number limited to the system including the sand particle and the surrounding aqueous phase without regard to the conduits in which the system is contained. The dimensionless group known as the Reynolds number usually relates the diameter of the conduit, the density of the liquid medium, the viscosity of the liquid medium, and the linear flow rate of the liquid medium in feet, pounds, and seconds as dimensions to determine the degree of turbulence in the system. In the special system under consideration, the diameter involved is the diameter of the sand particle, and the linear flow rate involved is the difference between the velocity of the sand particle and the velocity of the surrounding aqueous phase. In such a limited system, the change from laminar to turbulent flow occurs at particle Reynolds numbers between 2 and 5 rather than at the

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usual Reynolds numbers between 2,000 and 4,000 when measuring turbulence in fluid flowing through a cylindrical pipe.

As suggested above, the rapid acceleration of one medium in another, specifically of sand in flowing aqueous phase, may be brought about in any suitable manner. The preferred manner is to introduce the slurry of sand particles as a slowly moving stream at the inlet of an immersed centrifugal impeller along with sufficient additional aqueous phase. The rapid acceleration of each sand particle upon passing in contact with the aqueous phase in the accelerating region within a centrifugal impeller of suitable design will produce the required sand-water Reynolds number in the limited system set forth above. It is also within the scope of this invention to employ multiple accelerations, for example, by passing mixed aqueous and sand phases through a series of centrifugal pumps having between them surge tanks for decelerating the stream or in a specially designed pump where part of the discharge is decelerated and returned to the suction side. It is also within the scope of this invention to employ different means for producing the critical Reynolds number, such as a first stage wherein sand is introduced into the throat of a Venturi through which water is flowing and a second stage involving a centrifugal pump, with suitable deceleration between the two stages. In all of the processes mentioned, it is required that the viscosity of the hydrocarbon phase be maintained at less than two poises at the point where sand particles are accelerated; and temperature control of the various phases may be required.

The tar separated as set forth above remains tacky and is capable of recontaminating the sand, particularly any sand grains which were originally tar-wetted on any part of their surface. To avoid recontamination, it has been found that an adequate volume of aqueous phase must be present. Recontamination is substantially avoided if the volume ratio of water to the initial sand charge, exclusive of solvent, is maintained at at least four and preferably ten. In other words, a minimum of four volumes of water must be employed for each volume of sand measured before solvent is added to it; and when such volumetric proportions are observed, it has been found that tar recovery is excellent, usually involving more than 90 percent and frequently more than 99 percent of the tar in the original sand. A concomitant effect is that solvent loss to the tailings fraction is negligible.

The aqueous phase may be ordinary water, sea water, effluent from water treating plants, or water from other sources; but it is preferably fresh water having the pH adjusted to 8 or higher. Although water with a pH in excess of 8 is not essential for effecting the separation of tar from sand in accordance with this invention, water with high pH is beneficial in reducing interfacial tension between the liquid phase and the solid phase so that tar-wetted fine sand grains separate more readily from the hydrocarbon phase and are more easily recovered with the tailings fraction. Since it is more difficult to achieve high-shear conditions with small sand grains (fines) than with large ones, and the net density of grains with adherent tar and hydrocarbon solvent relative to water tends to be lower for fine grains than for coarse grains, separation of tar from large grains is usually readily achieved even at pH values below 8. For fine grains, the removal of tar, while not adding greatly to total tar recovery, may add substantially to the recovery of fine sand in the tailings. This of course also greatly reduces the contamination of recovered tar by fine sand. Therefore, the high pH water is not required so much to promote the recovery of tar as to promote the inclusion in the tailings of the fine sand fraction as clean sand. High pH water thus reduces the load on subsequent separation equipment which is required to remove suspended fines from the hydrocarbon phase and the aqueous phase.

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The process of this invention may be best understood with reference to the accompanying drawings. FIG. 1 illustrates schematically one process embodying this invention and FIG. 2 illustrates a sectional view of one centrifugal impeller suitable for use in practicing the invention. Both drawings are intended to be illustrative rather than limiting on the scope of the invention.

In the drawing, a rotary drum 10 is employed as a low energy mixing device to prepare tar sand for subsequent separation into a sand fraction and a tar fraction. A feed hopper 11 is charged with tar sand through line 13, solvent through line 15, and in a preferred embodiment, water through line 16. The material in rotary drum 10 is mixed sufficiently so that the solvent and the tar are combined to form a hydrocarbon phase that has a much lower viscosity than the original tar. The mixed phase system discharges from rotary drum 10 through a discharge hopper 12 and is transported via conveying means 17 into the separation zone 18. The conveying means 17 may be a pump and conduit system where the mixture in drum 10 is a slurry, or it may be a solids conveyer such as a screw or belt conveyer when the mixture discharging from drum 10 is not pumpable.

Separation area 18 is shown schematically as a box which is provided with a source of water 20 and recycle water 21. Within separation area 18 the material passing through means 17 is introduced into a rapidly flowing aqueous stream under conditions wherein each particle is accelerated in a water stream such that the difference in velocity between the particle and the water creates a Reynolds number in the system including the particle and surrounding aqueous phase of at least 150. Within separation zone 18 there will also be means for adjusting the temperature of the system when temperature control is essential to maintain the viscosity of the hydrocarbon phase less than two poises. As stated heretofore, sufficient quantities of light hydrocarbons such as gasoline will reduce the viscosity of the tar below two poises at ambient temperature; but when heavier hydrocarbons such as kerosene or gas oil are employed as the solvent, it may be necessary to adjust the temperature of the system so that the viscosity of the hydrocarbon phase is less than two poises at the point where each sand particle is accelerated.

This separation may be effected in centrifugal pumps, Venturi tubes, or other means wherein each sand particle is accelerated within the flowing stream of water to obtain the Reynolds number of at least 150 within the limited system set forth hereinabove. As a result of this high shear treatment, three separate phases are created which flow through line 22 into separator 23. The three phases in separator 23 are a liquid-hydrocarbon phase, a liquid-aqueous phase, and a solid sand or tailings phase. The hydrocarbon phase is usually dispersed in the aqueous phase at this point. The lower layer in separator 23 is the sand phase which may be removed through means 24. The sand phase will be wet, but it will contain substantially only water. Substantially the entire tar and solvent material are passed from separator 23 through line 25. Line 25 discharges into a separator 26 where the aqueous phase is separated from the hydrocarbon phase. The hydrocarbon phase, which is the product from the process, is recovered through line 27; and it may be subjected to further treatment to make it a more suitable material for its ultimate use. For example, the material in line 27 may be filtered to remove fines and may be subjected to fractional distillation to recover solvent for recycle to the process.

The aqueous phase passing through line 28 is recycled and may be subjected to treatment in water treating zone 30. Water treating zone 30 will normally adjust the pH of the aqueous phase to be in excess of 8 and will subject either all or some portion of the aqueous recycle stream to filtration or centrifugal separation to remove fines.

The aqueous phase employed in this example is added to the system before the low energy mixer through line 16, as fresh water feed through line 20 and as recycle aqueous phase through line 21. It is essential in the operation of this invention that the combined volume of these water streams and any additional water streams be at least four times the volume of the tar sand added through line 13. This volumetric relationship insures that each particle of sand from which tar is removed is surrounded with sufficient aqueous phase to prevent impact between sand particles and hydrocarbon droplets which tends to recontaminate the sand with hydrocarbon after separation is effected. Although the exact mechanism of insulating the separated tar particles from the sand is not known, it has been observed that, when the above-noted volumetric relationship between sand and water is observed, recontamination of the sand with hydrocarbon is substantially avoided. Under the conditions set forth herein, more than 99.5 percent of the tar has been separated from the sand, and a substantially hydrocarbon-free tailings fraction may be recovered.

The following is an example presented to demonstrate a specific embodiment of the present invention.

Tar sand from the Edna tar sand deposit located in San Luis Obispo County, California, was analyzed and found to contain 5.6 percent by weight of tar on a mineral sand that was primarily quartz and orthoclase. A measured weight and volume of this tar sand was introduced into a rotary drum mixer. Light stove oil was added to the rotary drum as a hydrocarbon solvent in a proportion of three weights of stove oil per weight of tar (not tar sand) and the drum was rotated until the material was thoroughly mixed. While the drum was rotated, water was added to the mixture in a proportion of ten volumes of water per volume of tar sand (excluding solvent) in the charge. Mixing was continued while the mixture was heated until a uniform slurry was produced at a temperature of 81° C.

The slurry was passed from the rotary drum to a vessel 40 as illustrated in FIG. 2. The vessel 40 was equipped with an impeller shown generally as 41, and the vessel was more than four times the diameter of the impeller. The impeller consisted of a central cylindrical housing 42 which formed a large axial passageway 43, and near the top of the impeller two smaller horizontal tubes 45 formed discharge passageways 46. A shaft 47 connected the impeller to a motor which caused the impeller to rotate at 2500 r.p.m.

The rotation of the impeller caused both the water and the sand to flow in a pattern indicated by the arrows. A rapid acceleration of each sand particle was experienced each cycle as the sand particles passed from passageway 43 into passageway 46 which was due both to the change of direction of the flow and to the increased velocity of the flow in passing from large passageway 43 into small passageway 46 under the influence of centrifugal force caused by rotation of the impeller. As each sand particle was accelerated in the rapidly moving water stream, the particle Reynolds number of the system including the sand particle and the surrounding water stream was at least 215. The sand particles also were decelerated upon exiting from passageway 46, and each sand particle was subjected to repeated accelerations and decelerations during the course of the treatment which was carried out for time periods ranging from 2 to 8 minutes.

At the end of the treatment, the contents of vessel 40 were drained into a second vessel wherein various phases could separate by gravity. Within the second vessel, the slurry separated into a lower tailings fraction, a central aqueous fraction, and an upper hydrocarbon fraction, and the three phases or fractions were separately removed from the second vessel and analyzed.

The tailings fraction was found to contain about 95 percent of the mineral in the original tar sand. The other 5 percent of the original sand was suspended in the aqueous phase and in the hydrocarbon phase as fines. The hydrocarbon fraction contained 94.7 percent of the tar in the original tar sand. The aqueous phase was substantially the same as when introduced except that it contained an unmeasured quantity of suspended fines.

Analysis of the tar-solvent hydrocarbon phase at 81° C. showed that it had a viscosity less than one poise.

From the foregoing description it is evident that the present invention provides a method for separating tar from tar sand that is efficient and economical, and one that does not entail high losses of valuable materials. Of particular importance is the fact that the relatively simple equipment and energy requirements of the process of this invention make it feasible to separate tar from tar sand at the mine site. This is an important economical factor in any process for recovering tar from tar sand because it avoids the need to transport the inert sand from the mine to a remote treating site, it avoids the problem of disposing of large volumes of sand at the treating site, and it avoids the problem of obtaining fill to restore the terrain where the tar sand was mined to its original contours. Thus, through the process of this invention tar sand can be mined, the tar recovered therefrom, the sand returned to fill the hole produced by mining, and only the crude petroleum recovered from the process need be shipped for further processing.

We claim as our invention:

1. A process for recovering tar from tar sand which comprises

(A) mixing tar sand with a hydrocarbon solvent to produce a mixture including sand particles and hydrocarbon phase;

(B) introducing the resultant mixture into a flowing aqueous stream wherein the characteristics of said mixture and said flowing aqueous stream at the time of mixing are:

(i) the hydrocarbon phase has a maximum viscosity of two poises

(ii) the differential velocity of the aqueous stream and each particle of solid phase is such that a Reynolds number exceeding 150 exists in the system including a particle and the surrounding aqueous phase

(iii) the volume ratio of aqueous phase to tar sand exclusive of solvent is at least four

(C) separately recovering a hydrocarbon fraction.

2. The process of claim 1 wherein said resultant mixture is mixed with the aqueous phase and then is introduced into the suction of a centrifugal impeller.

3. The process of claim 1 wherein said mixture is introduced into said flowing aqueous stream in the throat of a Venturi.

4. The process of claim 1 wherein said hydrocarbon solvent is gas oil and said mixture is maintained at a minimum of 50° C. when introduced into said flowing aqueous stream.

5. The process of claim 1 wherein at least a portion of the recovered aqueous phase is filtered to remove fines and recycled as a portion of said flowing aqueous stream.

6. The process of claim 1 wherein the aqueous phase has a pH of at least 8.

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